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## UNITS, METHODS, AND DEVICES OF MEASUREMENT UNDER SCIENTIFIC MANAGEMENT

In any paper covering a subject of such scope as this, one can hope to do little more than outline the subject, but even for such an outline it is necessary to show at the outset the scheme of division, recognition, and interrelation of the functions of scientific management.

This can be done best by showing graphically two plans of management. The first of these (see Fig. 1) represents what is variously known as military or traditional management. Here each man is responsible to one man only above him, and is in charge of all those below him. Thus it is the custom for any man to come in contact with one man above him only, the line of authority being single and direct. Traditional management has been used for centuries in military organizations, and has also been used many times in religious organizations and political organizations. The division is by men, by grades of men, rather than by functions.

Because the division is by men, it is almost impossible to measure and standardize the duties of the positions. Any attempt at such measurement and standardization makes clear the fact that the requirements of every position, with the exception of the most subordinate, demand men of a higher grade of development than the pay involved would justify. Moreover, as the supposed requirements of the positions are the result of guess or tradition rather than of measurement, successful standardization would be not only impracticable, but impossible.

Fig. 2 represents the lines of authority in functional or scientific management, or what would be called, but for objections of Dr. Taylor, the Taylor system of management. Here the division is by functions, the first functional division being the separation of the planning from the performing. Graphically, this separation is represented by the horizontal line. All functions above this line are of the planning, all functions below this line are of the performing. Note the functions shown on this chart, namely, four functions in

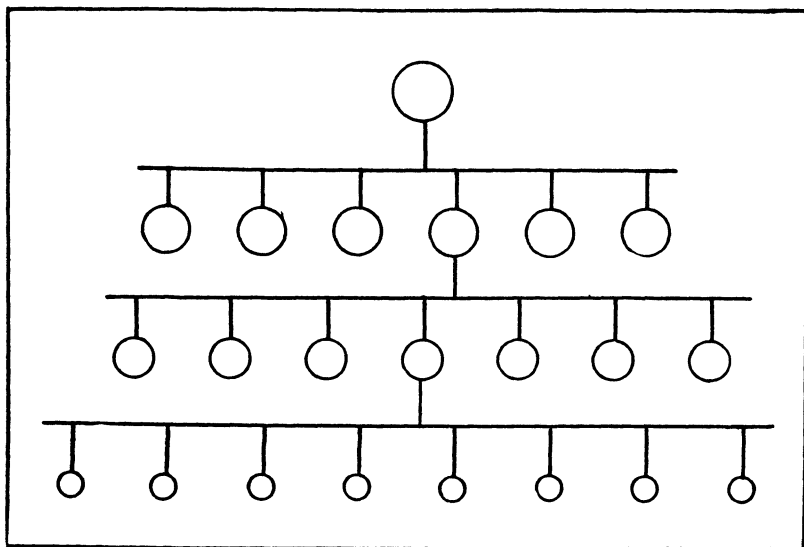


FIG. 1.—Diagram illustrating the routes of authority under the traditional or military type of management

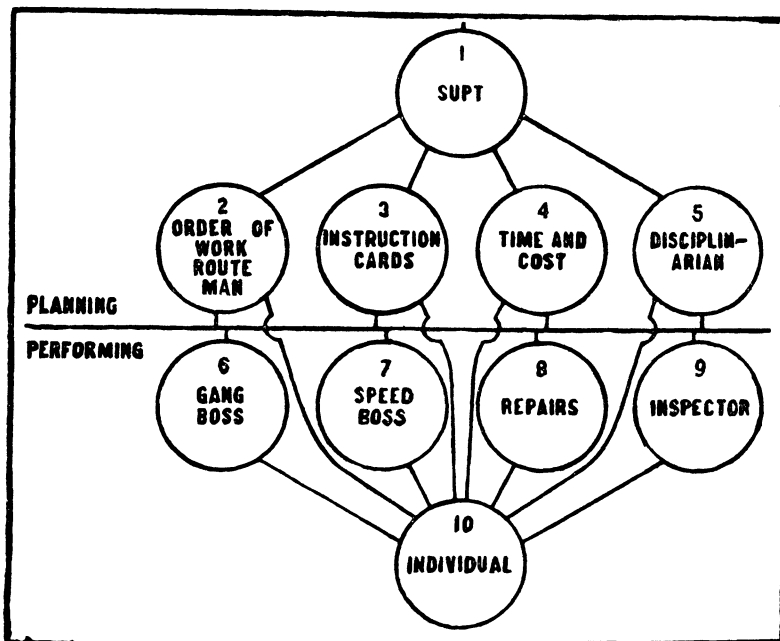


FIG. 2.—Diagram illustrating the principle of functional or scientific management

the planning and four functions in the performing. Note also their relation to each other, and to the individual worker. This chart shows one such worker represented by the lowest circle. There should be no objection to representing each individual worker by such a circle, but the relation of each such worker to those over him is the same. Hence, the lowest circle is typical.

It will be noted that the worker receives orders directly from eight different foremen. One might suggest, on observing this, that it has often been said that no man can serve two masters. This holds good today, even in scientific management. But under scientific management the worker does not "serve eight masters" nor eight functional foremen, but, on the other hand, he receives help from eight different foremen or teachers. In this way, his case is not very different from that of the student who receives instruction from eight different professors, in eight different studies.

The four functions in the planning department are represented by (2) route man and order-of-work man; (3) instruction cards; (4) time and cost; (5) disciplinarian. While we speak of each function as being represented by one person, as a matter of fact each function may include any number of individuals, according to the kind of work, and the number necessary so to perform that function as to eliminate all possible waste. Each one of these four men of the four functions in the planning department is supreme in his respective function. All deal directly with the worker, and all deal directly with the four functional foremen who are in the performing department.

Of the *performing* department we have four functions represented by (7) gang boss; (8) speed boss; (9) repair boss; (10) inspector. These functions, like those of the planning department, are represented by as many men as the nature and amount of work justifies. All such representatives deal, as the chart indicates, directly both with all individuals in the planning department, and with each individual worker.

The fact that all divisions represented by this chart are made on the basis of the nature of the work that is to be done, makes possible units for measuring and standardizing the duties of the man or men who hold the positions. The determining, grouping,

and assigning of these duties is done by measurement; hence the resultant standardization is successful. A statement of the duties of each function will make clear the amount of standardization that is possible.

*Route man.*—The duty of the route man (function No. 2) is to determine and plan in advance the path of each piece of material, worked and unworked, as it passes through the shop or as it is handled by each and every member of the organization who has anything to do with it. He is to decide the three dimensions of the path, and the route that the material is to pass through, whether it is to go to the stores or into temporary storage stations, or directly through the shop as fast as the operations connected with it will permit. His function is not simply to look after the details of the moving; he must also determine the “when” and in many cases the “who” as well as the “where.” Broadly, he determines the entire transportation career of the material. For example, in building operations, he would determine where the car was to be placed to be unloaded, where the material was to be unloaded, when it was to be moved into the building, and exactly what path it should follow across the floor, up elevators and to its final resting-place, and *who* should perform each operation.

Often the route man is able to simplify greatly the path of the materials, especially on large orders, by a rearrangement or routing of the machinery. We have had one case in our experience where it was cheaper, in a woodworking shop, to have the machinery placed on heavy pieces not attached to the floor, each machine operated by an individual motor, and to move the machinery, in order to accommodate the peculiarities of sequence of events of each particular order, when the order was large enough to warrant moving the machinery. The route man’s duties, also, oftentimes involve determining a new path, ordering that machinery not used be removed, so that he can route his material by a more economical method. After he has determined the exact path by which the material shall be routed, he embodies his conclusions into process charts, route charts, and route sheets; these illustrate his orders graphically and chronologically and are worked out in detail by the instruction card department.

*Instruction cards.*—It must not be supposed that the instruction-card function consists merely in the work of writing out the instruction cards. This is the name of the function in general, and it may be performed by several men in different lines and of varying capacity in the instruction-card function; that is to say, the department or function may be divided into measurable units or subfunctions. It is the duty of the instruction-card function to work out in detail and to devise and construct an instruction card describing the method of least waste for each element of the route sheets which are made from the route charts. The instruction-card department furnishes in the greatest possible detail such directions as will show two different classes of men their duties, namely: (a) the worker, who must know how to perform the particular work shown on the instruction card; and (b) the functional foremen in the performing department, who must know exactly what they are to see that the worker does perform, and exactly what they are to teach the worker in order that he may so perform his work as to conform to the instruction card.

*Time and cost.*—After the worker has performed his work, a return of the time that it took him to do his work, together with its cost, goes to the time and cost clerk (function No. 4) who calculates the pay-roll, including the bonuses, and the costs of each piece of subdivision of the work.

*Disciplinarian.*—The disciplinarian is the man who handles all matters in the entire organization pertaining to discipline. He must be a broad-gauge man, who is able to keep peace in the organization, to anticipate and prevent many disagreements and misunderstandings before they actually occur, and to arbitrate or judge fairly such disagreements as do take place.

The functions in the performing department are now to be considered.

*Gang boss.*—Function No. 7 is that of the teacher, still called "gang boss," as it was from that function that his work evolved. There may be many gang bosses in the performing department; in fact there are frequently five or more gang bosses of a single trade, with an over-gang-boss in charge. Altogether there may be in this function gang bosses of twenty or thirty different trades, in fact of

as many trades as are at work; or, possibly, one gang boss might look after two or more trades. The gang boss under scientific management is not the "strong arm" type of man represented by the mate of the vessel of former days, who boasted that he could thrash any man in the entire crew, and often did so for no other reason than to prove his words. Instead he is a man who knows of the measuring methods of motion-study and time-study, and who can teach the worker the methods shown on the instruction card. In order to get his best work, and to enlist his zeal, it is usually necessary to pay him a bonus measured by the bonus paid each and every man under him who in turn earns his bonus; and a double bonus if every man in his gang earns the bonus. For example suppose the gang boss received \$3.00 per day, and had twenty men working under him, he would be paid, say, in round numbers, 10 cents a piece for each man under him who received his bonus; and, if all twenty of the men received their bonus, he would receive a double bonus of 20 cents apiece for the entire gang.

It can readily be seen that such a plan of management as this will bring out co-operation as would no other plan; and it should be stated here emphatically that there is nothing that can permanently bring about results from scientific management, and the economies that it is possible to effect by it, unless the organization is supported by the hearty co-operation of the men. Without this there is no scientific management.

Moreover, since the conditions which bring about the co-operation are measured and standardized, the result is stable. Co-operation without standardization is a most unstable thing, likely to disappear at any moment with a change of the individuals supposed to co-operate.

*Speed boss.*—Regardless of the popular impression as to his duties, the speed boss (function No. 8) does not speed up the men. In fact, he has very little to do with speeding the men. His duty is to see that the machinery moves at the exact speed called for on the individual instruction card. It is obvious that there is some one speed that is more desirable than any other speed; for example, the speed of a buzz planer or a circular saw is very dangerous when it is too slow, while on the other hand, the speed of a fly-wheel of an

engine is very dangerous when it is too fast. What is most desirable and safe is the speed that the instruction card man attempts to set on the instruction card, and it is the duty of the speed boss to see that the machinery runs at all times at exactly the prescribed speeds. He not only shows the worker how he can make his machine run at the speed called for, but, if there is a question as to its being possible to run at this speed, he must be prepared to teach the worker by doing the work himself, or provide a man who can comply with the requirements of the instruction card.

*Repair boss.*—Function No. 9 is that of the repair boss. His duties consist principally in seeing that all machines are kept clean and in proper condition, and in carrying out repairs and overhauls, such as are called for on instruction cards and in standing orders that are given to him at regular, predetermined intervals. In this way breakdowns are so far as possible avoided. The repair boss, however, must be a resourceful man, prepared, in case of emergency, to jump in and repair any such breakdowns as may occur, even in the absence of precise directions or of instruction-card specifications.

*Inspector.*—Function No. 10 is that of the inspector. His duties are decidedly different from those of the inspector under the old type of management. For example, his inspection must result in prevention of error; in constructive criticism, not destructive criticism. His decisions are predetermined by measurable limits of error furnished both him and the workman by the instruction-card department.

Many times, under traditional management, the inspector comes around after the work is done, condemns it, and walks away, leaving it to others to see that the work is replaced to his satisfaction. Under scientific management the inspector is required to stand near the worker when he is handling a new piece of work for the first time, in order to see that the worker thoroughly understands his work as it progresses. Thus the first unit of the material is less likely to be spoiled. If the worker has a task of, say, fifty pieces, the inspector inspects the first piece most carefully, to make sure that the worker knows exactly what he is to do, how he is to do it,

and the quality and the prescribed tolerances of drawing and instruction card.

*The workman.*—As for the individual worker, it will be seen that he does not receive merely an instruction card, telling him by units what he is to do, how he is to do it, how fast he is expected to do it, the prescribed quality of the work which must be done, and how much pay over and above his usual day's wages he will surely get if he does all that is called for on his instruction card. He receives also personal teaching. The gang boss acts as his teacher constantly; the speed boss he can call on at all times to assist him with the speeds; the repair boss co-operates with him to see that his machine is constantly kept in such repair that he can earn his bonus, and the inspector will also teach him at any time, and show him wherein he is making a deviation from the quality called for. Moreover, the functional foremen in the planning department are ready, at call, to explain their instructions. Thus he has every help that is possible, to enable him to earn the exceptionally high wages that are offered by this form of management. He is assured of the "square deal" from the foremen who are over him, and in case others whose work affects his are deviating from their measurable schedules, programs, or conduct, he always has the same opportunity to appeal to the disciplinarian, that a foreman would have in case the worker was not doing his work as well as he could do it, or was not trying to co-operate with the other workers.

Having described briefly some of the many divisions and interrelations of the functions of scientific management and their foundation upon measurement, we are now ready to concentrate upon one, to show by a typical case how division of elements down to fundamental units may result in (a) determined units; (b) measured units; (c) devices of measurement. Let us take for a typical example two subfunctions of the instruction-card function, namely, motion-study and time-study, and carry them to micromotion-study.

Motion-study is a subfunction of function No. 3 of the planning department. Just as scientific management is divided into functions, so each function is divided into subfunctions, the basis of division being the same, i.e., duties, not men (see Fig. 3). Motion-

study is related to all subfunctions of the instruction-card function, but is most closely related to time-study and to the determining of methods of least waste. It is related to time-study in that it determines what path a motion is to follow, while time-study determines how swiftly the path is to be traversed and the amount of rest

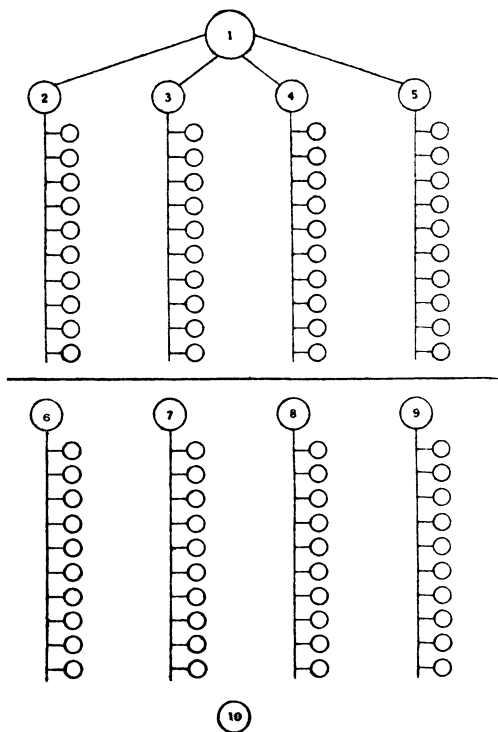


FIG. 3.—The subfunctional chart

required to overcome resulting fatigue. The two measure work and determine the best method by which the work can be done.

Motion-study, time-study, micromotion-study, fatigue-study, and cost-study are important measures of scientific management, by which the efficiency of each function and subfunction is determined, tested, and checked. The unit to be chosen for intensive study is determined by the amount of time and money that it is possible to save by the investigation. This unit is determined by the following

method. The work selected is divided into natural subdivisions or cycles of performance. Each cycle is then subjected to motion study, to determine the best method to use in performing the work. This method is divided into the smallest practicable units. These units are timed. The timed units are then again subjected to motion study, for more intensive study of method. Subdivided motions result. These are again timed, and so the process proceeds until the further possible saving will no longer warrant further study, or the available appropriation of time or money is exhausted. The most efficient motions, as determined by the tests of motion-study and time-study, are then synthesized into a method of least-known waste.

This outline of the steps in taking motion-study and time-study is necessarily incomplete, lacking, as it does, discussion of the selection of the observer, the observed worker, and many other elements of scientific management.

As for the particular device by which the measurements are made, the choice depends mainly on the equipment available. Standards have been improved even by merely timing the work by counting, where no timing devices were at hand. Excellent work had been done with stop watches. But we advocate the use of micromotion-study in all work demanding precision. Micromotion-study consists in recording the speed simultaneously with a two or three dimensional path of motions by the aid of cinematograph pictures of a worker at work and a specially designed clock that shows divisions of time so minute as to indicate a different time of day in each picture in the cinematograph film. Through micromotion-study not only is the measurement more accurate than it could possibly be through any other method, but also the records are so complete, permanent, and accessible that they may be studied at any time and place by anyone. The advantages of this in standardizing work, and most especially in teaching workers, are obvious.

The result of measurement, as outlined above, is standards synthesized from measured ultimate units of the workers' manual motions.

Morris Llewellyn Cooke, Director of the Philadelphia Depart-

ment of Public Works, in *Bulletin 5* of the Carnegie Foundation for the Advancement of Teaching, created for the word "standard" a definition which is itself "standard" in the scientific management sense. He said:

A standard under modern scientific management is simply a carefully thought-out method of performing a function, or carefully drawn specifications covering an implement or some article of stores or of product. The idea of perfection is not involved in standardization. The standard method of doing anything is simply the best method that can be devised at the time the standard is drawn. Standard specifications for materials simply cover all the points of possible variation which it is possible to cover at the time the specifications are drawn. Improvements in standards are wanted and adopted whenever and wherever they are found. There is absolutely nothing in standardization to preclude innovation. But to protect standards from changes which are not in the direction of improvement, certain safeguards are erected. These safeguards protect standards from change for the sake of change. All that is demanded under modern scientific management is that a proposed change in a standard must be scrutinized as carefully as the standard was scrutinized prior to its adoption, and further that this work be done by experts as competent to do it as were those who originally framed the standard. Standards adopted and protected in this way produce the best that is known at any one time. Standardization practiced in this way is a constant invitation to experimentation and improvement.

This experimentation and improvement are done by time and motion study *before* the standards are made. Thus the resulting standard is in so far perfected that only the invention of a new device will make a change in the standard necessary. The fact that such devices are often the result of the motion study also assists in making the standards that are incorporated from the completed study more permanent.

As was well shown by Mr. John G. Aldrich, in a paper read before the American Society of Mechanical Engineers, in December, 1912, the waste motions eliminated by such measured standardizing can scarcely be overestimated. This has been demonstrated in many lines of activity. The standard toolroom, the standard assembly packet and bench for assembling, the standard desk in the planning department—these are but illustrations of the application of this principle. And it is not necessary that the illustrations be drawn from the field of shopwork. It has been applied to many of

the outdoor trades. We are now co-operating with famous surgeons in the study of the elementary motions used in surgery, and we are investigating the muscular activity that underlies the "singing tone" of the skilled musician, to mention two recent invasions of the fields of science and art.

There will be those who will say that no such theory, methods, or devices can ever supplant the need and usefulness of the first-class mechanic or the genius in the trades, arts, and professions. With this we humbly agree. But even two geniuses in the same work may differ greatly in their methods as a whole; and isolating and examining the ultimate units of their work may show that motions made by one of the geniuses may be found absent, and unnecessary, in the work of the other. A synthesis of the best of the units of methods of each would present a method better than any arrived at by the spontaneity of any one genius, no matter how great. Surely the presentation of the best method, however discovered, must be of the greatest value to all below the grade of best.

Meantime, all workers are sharing in the savings made possible by the elimination of waste. They are being trained in habits of least wasteful motions, and are becoming more efficient both in their working and in their non-working hours. They learn to "think in elementary motions," and to submit their activities in all lines to the tests of motion and time study.

The great need now is for more efficient co-operation, that work done by one investigator may not be needlessly repeated by another. Through such co-operation only can come the savings that will allow of refinements of the units, methods, and devices of measurement, and that will result in progress that is definite, constant, and lasting.

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